

# Using AREDN Software to Create a Ham Radio IP Network

Updated 1/4/2023 – Vers. 5.2

Orv Beach, W6BI

[w6bi@arrl.net](mailto:w6bi@arrl.net) / [orv.beach@gmail.com](mailto:orv.beach@gmail.com)


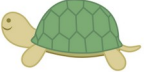


Technical Specialist, ARRL Santa Barbara Section

AREDN Ambassador



# Ham Radio IP Networking with AREDN Software

Comparing speeds (modulation rates, not throughput)

- Packet radio is 1200 baud (1 baud = 1 bit/second)
  - That's .0012 Megabits/second (!) 
- PACTOR IV is up to 5,200 bits/second (but not normally allowed in the U.S.) 
- VARA FM (software modem) can be up to 25 kilobits/second 
- Ham radio network links can be more than 100 Megabits/second 
- AREDN networking uses commercially available access points from Ubiquiti, TP-Link, Mikrotik and GL.Inet
- The access points are loaded with custom firmware from AREDN; they become ham radios.
- They can then be used to create a ham radio IP network (the "Hamnet")

# Amateur Radio Emergency Data Network (AREDN) Software as of 1/4/2023

Supports:

- Four brands of equipment, 80+ different models, across four ham bands
- Internet tunneling between nodes, to bridge RF gaps (requires addition of Mikrotik hAP AC Lite to shack network)
- Allows operations in Part 97 (ham) channels
- MIMO (Multiple Input / Multiple Output) + 802.11n operation - enhances throughput substantially compared to older devices
- The software provides DNS & DHCP services, route discovery and routing information – makes it relatively easy to get set up and connected.

# The Digital Networking Bands

## ● 902-928 MHz

- not used much in urban and suburban areas (very noisy): only one 5 MHz wide channel. We're secondary on that band, the gear is relatively expensive and getting hard to find.

## ● 2.4 GHz – 2300-2450 MHz

- Only one usable 10 MHz wide Part 97 channel (Channel -2); Channel -1 may work OK away from cities.
- Noisy due to splatter from poorly designed Part 15 wireless gear

## ● 3 GHz – 3300-3500 MHz

- The good news: it's all ours! No U.S. Part 15 in this band
- The bad news: we have to buy export equipment and it's almost ~~double~~ quadruple the price of 2 or 5 GHz equipment
- The worse news: in April 2022, the FCC gave half of it to the 5G carriers; we'll find out the fate of the other part of the band in the future.

## ● 5 GHz Band – 5650-5925 MHz

- Lots of channels.
- The Part 97 band overlaps a lot of Part 15 channels, which can be useful for spreading traffic out.
- We're secondary in this band. In October of 2020 the FCC took away primary occupancy of this band from the DOT (Department of Transportation). They're allowing Part 15 users to spread into the entire band in the near future.



## Line of Sight

"Microwaves can  
go ~~15~~ miles or  
through one tree"

~~25~~  
35



Two's Company

Tree's a Crowd...

# Wireless Access Points running AREDN software

They're like handie-talkies:

- They're low power (typically 600 milliwatts)
- They're limited to line of sight
- So they usually communicate through hilltop sites
- If your node hears multiple hilltops, it will always choose the best signal for its default route. So there's no point in using an omni antenna. A dish pointed at the strongest node is recommended.

Networking is a modern ham radio activity

But it's just infrastructure. It doesn't do anything...

It's all about the “Services”

- **Services = things you can actually use**  
**Some examples:**

- Messaging/Email
- Keyboard to keyboard (text)
- Voice
- Video
- Document editing/management
- File Sharing Services
- Web servers
- Repeater linking
- ***Anything else you can think of subject to the Part 97 regulations***

## **Messaging**

**The future of EmComm is not  
voice, but rather data**

## Plain old Email

- Email servers & clients, using standard SMTP
  - Thunderbird, etc.
  - Web clients are available (e.g., Roundcube)
  - Requires tweaks to AREDN node config
- Winlink and a ham radio network were made for each other!

# Winlink

## (Winlink Global Radio Email)

A worldwide messaging system, originally for boaters. Can use:

- **On HF**
- ALE (Automatic Link Establishment)
- AX.25 Packet Radio
- Robust Packet (proprietary SCS protocol)
- PACTOR, PACTOR 2, PACTOR 3, PACTOR 4\*
- VARA/HF (software modem)
- ARDOP (older generation software modem; falling out of use)

\*Only legal in the U.S. during emergencies, when authorized by FCC

# Winlink

## On VHF

- AX.25 Packet Radio
- APRS
- VARA/FM
- AREDN network
  - ◆ much faster, no digipeating required
- Has a large set of standardized messaging templates. (e.g. ICS, USGS, FEMA)

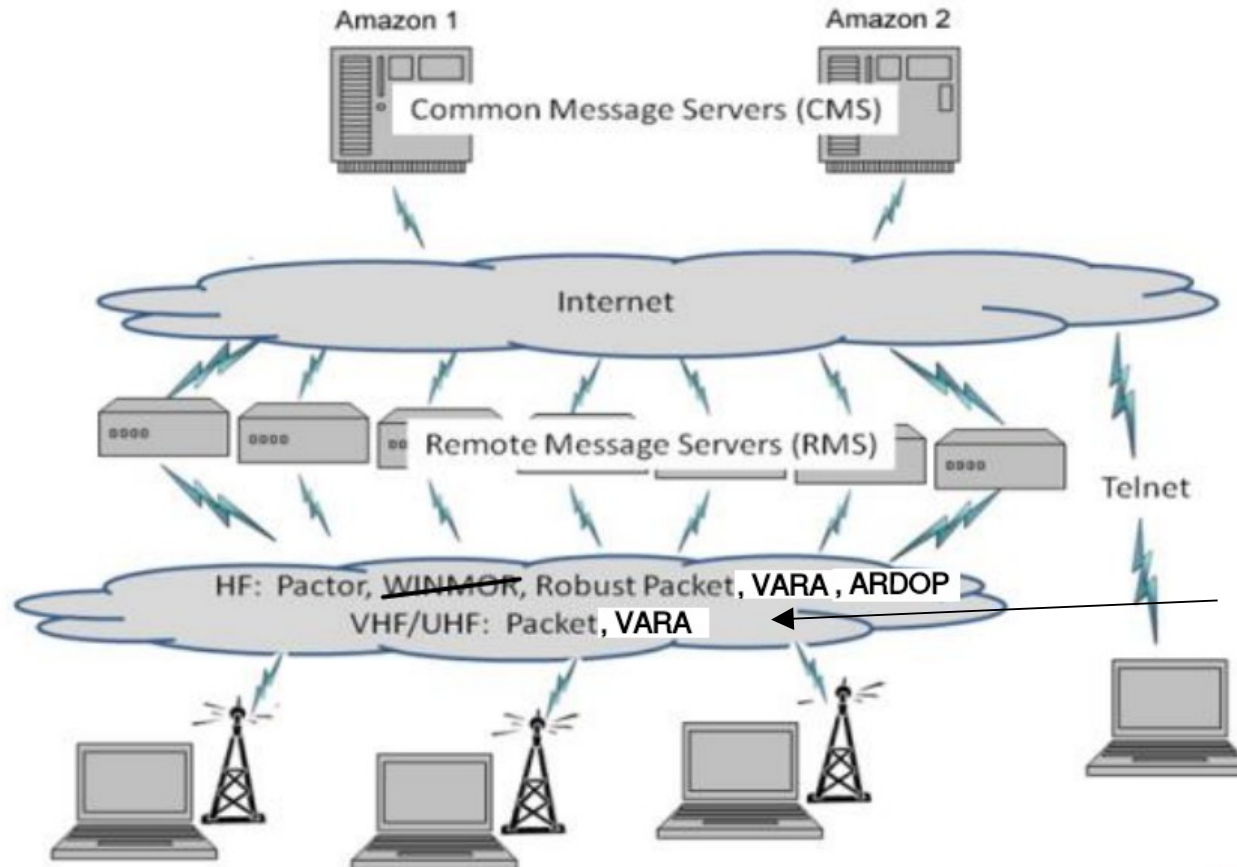


# Winlink Architecture (Conventional Mode)

- CMS

- RMS  
(gateway)

- Client  
(you)



Ham networking  
goes here

# Winlink Express Client

Winlink Express 1.5.35.0 - W6BI

W6BI Settings Message Attachments Move To: Saved Items Delete Open Session: Telnet Post Office Logs Help

In Telnet Post Office session.

System Folders	Date/Time	Message ID	Size	Source	Sender	Recipient	Subject
Inbox (0 unread)	2021/03/10 18...	QJE5JUWYO...	176	KE6MLF	KE6MLF	W6BI	Howdy
Read Items (0)	2021/03/10 00...	LNTFUR6YP...	434	AJ7C	AJ7C	W6BI	Re: CW ID?
Outbox (0)	2021/03/09 22...	BWVVIS1AY...	269	SMTP	SMTP:winlink...	W6BI	Your Winlink Checkin Was Received
Sent Items (51)	2021/03/07 23...	QQ8WWM8P...	436	AJ7C	AJ7C	W6BI	Re: Other bands?
Saved Items (0)	2021/03/07 19...	S33XEVUO2...	920	AJ7C	AJ7C	W6BI	Re: What are these?
Deleted Items (2)	2021/03/06 04...	PGRPLPGF6...	727	AJ7C	AJ7C	W6BI	Re: What are these?
Drafts (0)	2021/03/04 22...	5JCNR37ET...	464	AJ7C	AJ7C	W6BI	Re: More HF coverage
Personal Folders	2021/03/04 22...	111BSIVR6ZF...	469	AJ7C	AJ7C	W6BI	Re: What are these?
Global Folders	2021/03/02 22...	OSIR2S1WB...	268	SMTP	SMTP:winlink...	W6BI	Your Winlink Checkin Was Received
Contacts	2021/02/28 20...	FUBFTPVZR...	1045	AJ7C	AJ7C	W6BI	Re: First HF connection!

Message ID: QJE5JUWYO609  
Date: 2021/03/10 18:42  
From: KE6MLF  
To: W6BI  
Source: KE6MLF  
Downloaded-from: Post-office:WINLINK - AI6BX-MESH-PC  
Subject: Howdy

Is this working?

[Message receipt requested]

5022803062@VTEXT.COM  
5052803062@VTEXT.COM  
8055513008@VTEXT.COM  
8055513008@VZWPIX.COM  
AB6BW  
AI6BX  
AJ7C  
KE6MLF  
KE6WEZ  
KG6WXC  
ORV.BEACH@GMAIL.COM  
W2AYZ  
W6BI  
WINLINK@VCCOMM.ORG

Setup can be complex, depending on how many modes your station is set up for: Pactor, VARA, AX.25 packet, AREDN network, etc.

# Keyboard to Keyboard

- **MeshChat**
  - Runs on a Raspberry PI
  - Multiple channels can be created
  - Automatically finds other MeshChat servers
  - Web-based interface
  - Built-in “dropbox”

# MeshChat example

The screenshot shows the MeshChat v1.0 web interface. At the top, there are navigation tabs: CHAT, FILES, STATUS, and LOGOUT. The STATUS tab is active, showing 'Zone: LWMeshChat' and 'Call Sign: K7FPV'. A callout points to the STATUS tab saying 'Shows sync status with other nodes'. Another callout points to the 'Zone' text saying 'Zone'. Below the navigation, there's a 'Send a Message' section with a 'New Message' input field and a 'SEND' button. A callout points to the input field saying 'Enter new messages here'. Below the input field, there's a 'Channel:' dropdown menu set to 'Everything'. A callout points to this dropdown saying 'Which channel to send the message to'. To the right of the 'Send a Message' section, there's a 'Mesh Chat Users' section showing a table with columns 'Call Sign', 'Node', and 'Last Seen'. The table contains one entry: 'K7FPV', '[laytonwestdistrict](#)', and '10/11/16 10:51 AM'. A callout points to the 'Node' column saying 'Search Messages'. Another callout points to the 'Last Seen' column saying 'Users logged in'. Below these sections, there's a 'Messages' section with a 'Search:' input field and a 'Channel:' dropdown menu set to 'Everything'. A callout points to the 'Search:' input field saying 'Messages in the db'. Another callout points to the 'Channel:' dropdown menu saying 'Filter messages by channel'. The 'Messages' section contains a table with columns 'Time', 'Message', 'Call Sign', 'Channel', and 'Node'. The table contains two entries: one from '10/11/16 10:50 AM' with the message 'This is meshchat. It is a messaging and file sharing app for AREDN mesh networks.', and another from '10/11/16 10:50 AM' with the message 'It is fully redundant and decentralized. It works with spotty links and requires very little bandwidth.'.

**CHAT** **FILES** **STATUS** **LOGOUT**

**File Sharing**

**Zone:** LWMeshChat **Call Sign:** K7FPV

**Mesh Chat v1.0**

**Node:** laytonwestdistrict  
**Updated:** 14 seconds ago

**Send a Message**

**New Message**

Enter message here

**Channel:** Everything **SEND**

**Mesh Chat Users** 1

Call Sign	Node	Last Seen
K7FPV	<a href="#">laytonwestdistrict</a>	10/11/16 10:51 AM

**Messages**

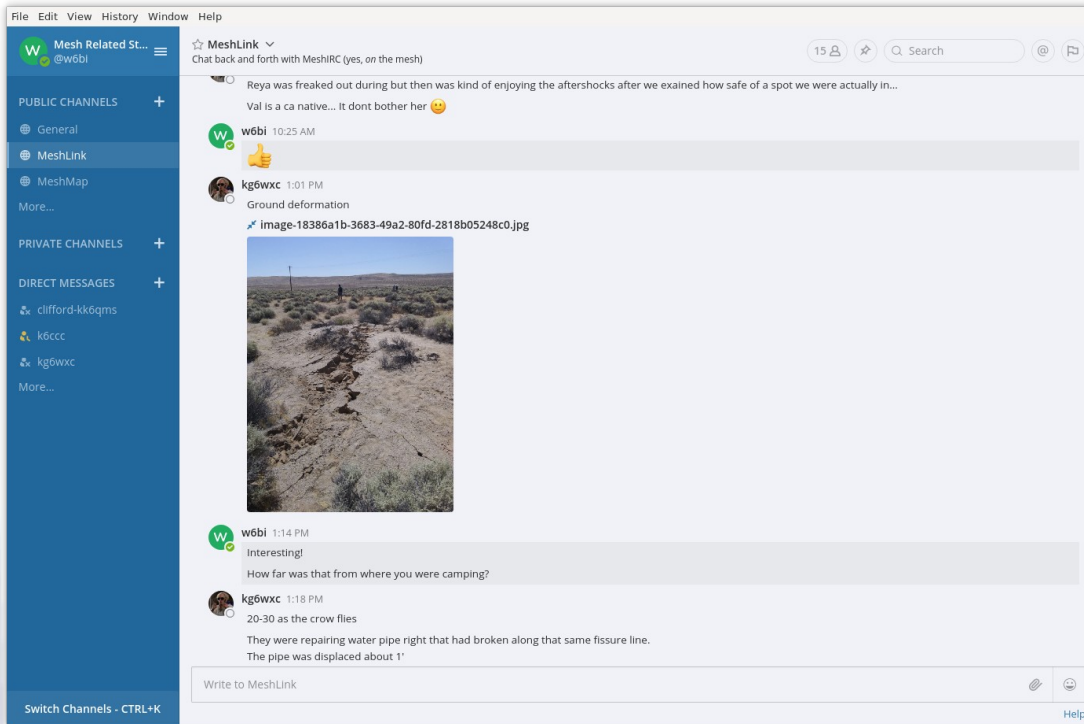
**Search:** Enter search **Channel:** Everything

Time	Message	Call Sign	Channel	Node
10/11/16 10:50 AM	This is meshchat. It is a messaging and file sharing app for AREDN mesh networks.	K7FPV		
10/11/16 10:50 AM	It is fully redundant and decentralized. It works with spotty links and requires very little bandwidth.			

# Communication “Hubs”

- Mattermost & RocketChat - like Slack
- Text & pictures
- Multiple channels available
- Web access + Windows, IOS, MacOS, and Android apps available

# Mattermost



- Screenshot of ham network Mattermost server in Ventura County
- Also linked to another Mattermost server in San Bernardino County (100 air miles, 150 network miles away)
- Also linked to a Mattermost server on the Internet

# VOIP (Voice Over IP w/Phones)



- Phone calls over the ham radio network
- Old photo, pre-deployment:
  - Old Cisco VOIP phone \$25
  - Grandstream VOIP phone switch ~\$275





- VOIP PBX installed in mountaintop repeater building (K6PVR – Sulphur Mountain, Ojai, California)
- Voice mail, conference calls, etc
- About 30 extensions: ham and served agencies (PD EOCs, hospitals, etc.)



# VOIP (Voice Over IP Phones)



- Grandstream GXP 1625 VOIP phone (about \$35) Two lines, POE-capable
- Other brands and models will work (Be careful buying old phones – make sure they can work with the SIP protocol; some are proprietary).
- Showing a missed phone call
- Showing one or more voice messages waiting

## Another VOIP PBX



- Raspberry Pi 3 running FreePBX
- Deployed to the adjacent valley; trunked to first PBX
- Offers extensions, voice mail, conference bridges, etc.

# Collaboration Servers!

- Like the gamers use to coordinate their teams
- Voice and/or video chat. Very useful – and fun!
- TeamSpeak, Mumble, TeamTalk, etc.
- Teamtalk provides these features:
  - One to one chats
  - Many to many (chat rooms)
  - Can set up as many channels as necessary
  - Multiple, **simultaneous** conversations possible – all **full duplex** (you can interrupt whomever's speaking :-D )
  - Speaker/microphone or headset (**HIGH quality audio**; not limited to 300-3,000 Hz like regular ham radio)

## Collaboration Servers! (cont.)

- PTT, VOX or open mic (each audio stream uses 50-100 kbps (up & down) – minimal load on a healthy network)
- File sharing and desktop sharing are also available
- The Teamtalk server runs nicely on a Raspberry Pi (RPI 3: typically < 10-15% CPU utilization)
- Clients available for Windows, Debian Linux, MacOS, IOS, and Android

# Teamtalk Weekly Net – Call of person talking has green background; when they unkey it turns yellow

The screenshot displays the TeamTalk v. 5.4 application window. The title bar reads "TeamTalk v. 5.4". The menu bar includes "Client", "Me", "Users", "Channels", "Server", and "Help". Below the menu is a toolbar with icons for various functions. The main interface is divided into three panes. The left pane, titled "K6PVR Ventura County Teamtalk (14)", lists 14 users and two auxiliary channels. The user "KM6FQ Dave" is highlighted with a yellow background. The middle pane has tabs for "Chat", "Video", "Desktops", and "Files", with "Chat" selected. The chat log shows a series of messages with timestamps and user names. The last message is from "Brian - AE7WY" and contains a URL. The bottom pane shows a microphone icon and a status bar with "RX: 0.00KB TX: 0.00KB".

TeamTalk v. 5.4

Client Me Users Channels Server Help

K6PVR Ventura County Teamtalk (14)

User	✓	✓	✓	✓
Brian - AE7WY	✓	✓	✓	✓
Dale WA6MZW Cathedral City	✓	✓	✓	✓
Dave km6fq	✓	✓	✓	✓
Endaf - N6UTC Long Beach.	✓	✓	✓	✓
eric - kg6wxc - oxnard	✓	✓	✓	✓
Ian AJ6GZ - Redlands	✓	✓	✓	✓
Jim - K6CCC	✓	✓	✓	✓
K3CAQ Andy Thousand Oaks	✓	✓	✓	✓
K6CCC iPhone	✓	✓	✓	✓
Kevin - AJ7C - Culver City	✓	✓	✓	✓
<b>KM6FQ Dave</b>	✓	✓	✓	✓
Orv - W6BI - Simi Valley	✓	✓	✓	✓
Ryan - K1BLU - Lakewood	✓	✓	✓	✓
Steve - K6CRW	✓	✓	✓	✓
Aux Channel 1 (0)				
Aux Channel 2 (0)				

Chat Video Desktops Files

2020-04-15T20:04:05 \*Ryan - K1BLU - Lakewood left channel  
2020-04-15T20:04:11 \*Ryan - K1BLU - Lakewood joined channel  
2020-04-15T20:04:18 \*Endaf - N6UTC Long Beach. joined channel  
2020-04-15T20:06:26 <Endaf - N6UTC Long Beach. > no im here  
2020-04-15T20:07:49 \*K3CAQ Andy Thousand Oaks joined channel  
2020-04-15T20:07:58 \*Endaf - N6UTC Long Beach. left channel  
2020-04-15T20:08:43 \*K3CAQ Andy Thousand Oaks left channel  
2020-04-15T20:09:17 \*K3CAQ Andy Thousand Oaks joined channel  
2020-04-15T20:13:29 \*Dale WA6MZW Cathedral City joined channel  
2020-04-15T20:14:45 \*Endaf - N6UTC Long Beach. joined channel  
2020-04-15T20:15:11 \*Endaf - N6UTC Long Beach. left channel  
2020-04-15T20:18:11 \*Endaf - N6UTC Long Beach. joined channel  
2020-04-15T20:19:47 \*Endaf - N6UTC Long Beach. left channel  
2020-04-15T20:20:16 \*Endaf - N6UTC Long Beach. joined channel  
2020-04-15T20:24:12 \*Dave km6fq joined channel  
2020-04-15T20:25:56 \*Dave km6fq left channel  
2020-04-15T20:26:14 \*Dave km6fq joined channel  
2020-04-15T20:26:30 \*Kevin - AJ7C - Culver City joined channel  
2020-04-15T20:26:32 \*Dave km6fq left channel  
2020-04-15T20:26:37 \*K3CAQ Andy Thousand Oaks left channel  
2020-04-15T20:26:45 \*Dave km6fq joined channel  
2020-04-15T20:27:41 \*eric - kg6wxc - oxnard joined channel  
2020-04-15T20:27:41 \*eric - kg6wxc - oxnard left channel  
2020-04-15T20:28:12 \*eric - kg6wxc - oxnard joined channel  
2020-04-15T20:28:37 <eric - kg6wxc - oxnard> me 2, client is junk now.  
2020-04-15T20:29:06 \*K3CAQ Andy Thousand Oaks joined channel  
2020-04-15T20:29:24 <Brian - AE7WY> <rtsp://AE7WY-Cam-Clark-WY.local.mesh:554/s2>

RX: 0.00KB TX: 0.00KB

Send

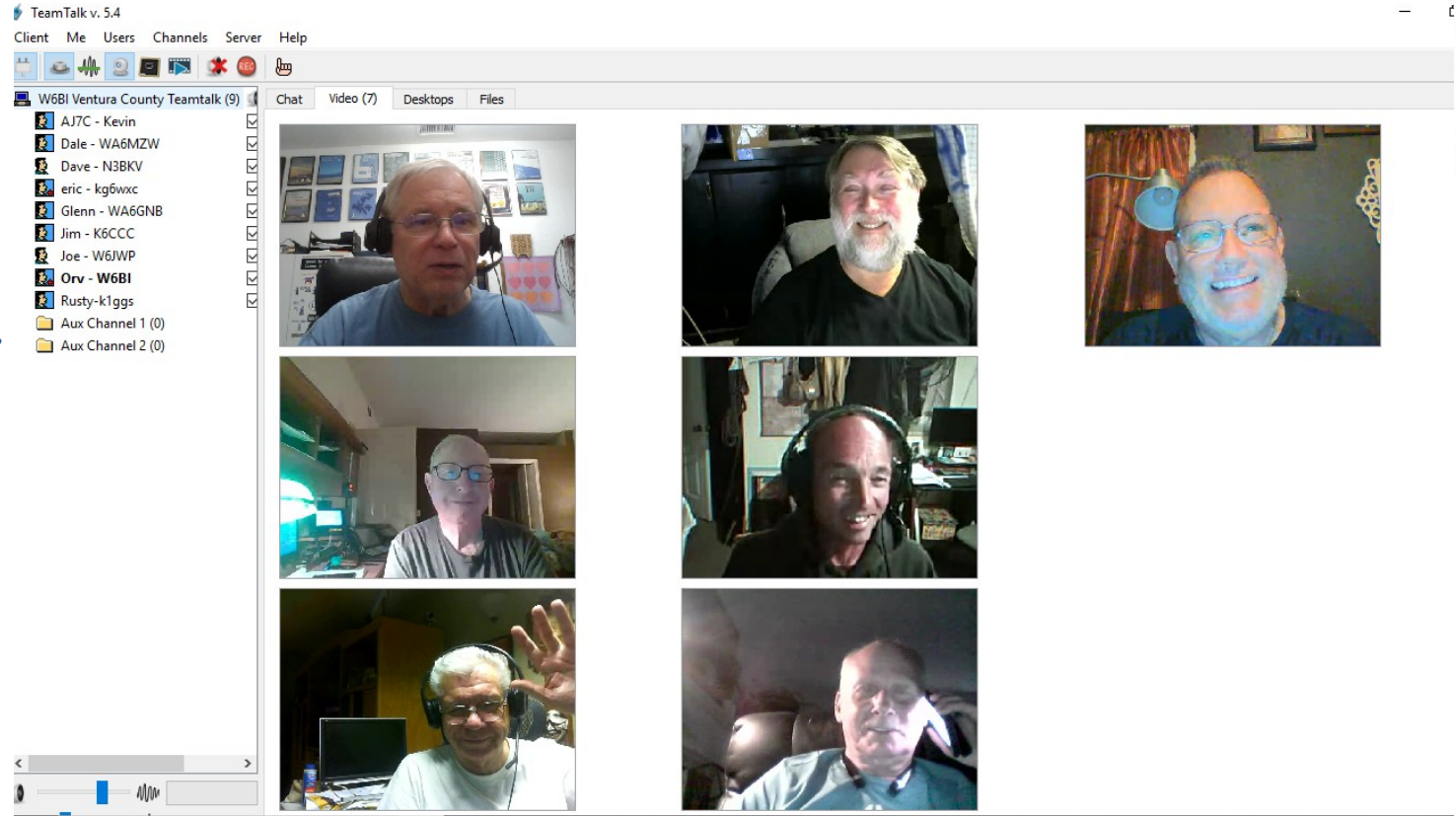
Push To Talk: Alt



# Teamtalk Net

## Video can be bandwidth-heavy. It's optional

Aux channels; switch to  
one by double-clicking  
Green – who's talking  
Yellow – who talked last



# Video – Webcam Examples

Field day setup, 2016

As the crow flies, about seven miles. But two ranges of hills were in the way.

Via network - 3 hops on 2.4 & 5.8 GHz, about 40 miles total path length.





## Typical PTZ camera view





# The Thomas Fire – Ventura, CA Dec 2017. Streamed to YouTube for wide viewing



# **The Woolsey Fire – Thousand Oaks, CA 11/2018**

## **Also streamed to YouTube**



# The Woolsey Fire – Thousand Oaks, CA 11/2018

## Also streamed to YouTube






# Brush fire in Santa Susana Pass – right below radio site. Also streamed to YouTube




# Document Sharing

- Etherpad - like Google Docs (but no spreadsheets)
- NextCloud cloud storage
- Several others

# Etherpad example (not ham)


 **EtherPad**


Share this URL: <http://etherpad.com/jeresig-demo>


 New pad


hide »

Connected Users

 John Resig  
24.61.14.106/Firefox3.0.3  
[edit name/color](#)

 aaron  
64.81.66.253/Firefox3.0.3

 Aaron (laptop)  
64.81.66.114/Firefox3.0.3

 jd  
64.81.66.219/Safari3.1.2

[invite more people...](#)

Saved Revisions

Save Now

[Revision 1](#) saved 5 hours ago by John Resig (24.61.14.106)  
[view](#) | [restore](#)

Options

☒ Highlight who typed what.

☒ Wrap long lines.

☒ Show line numbers.

☐ Use full window width & height.

☐ Highlight JavaScript syntax.

Feedback

9 Yo

10 Hello?

11

12 A hoy hoy!

13

14 Neat! It seems like it's going in real-time.

15

16 Yes, it is! (AppJet has a scalable implementation of comet).

17

18 Nice. That's certainly something that's always a pain to try and get right.

19

20 Yeah, and we went to great pains to make sure it works on IE6 and stuff.

21

22 Awesome. So this is all part of that .jar, then?

23

24 Not released yet. The .jar lets you run apps that currently can run on appjet.com. Just 1-pagers basically.

25

26 EtherPad is the poster child for "project barmitzvah" -- wehre AppJet comes of age :). We'll release the new version of AppJet for all developers, open source, shortly afterwards.

27

28 Nice. So that big release is also happening next Wed.? (not necessarily the Open Source release).

29

30 That's actually going to take a littl bit of time. Next wednesday is just EtherPad and the announcement of the new platform coming. The new platform (not sure what to call it yet, maybe JavaScript On Jets (I own javascriptonjets.{com,net,org} :)))

31

32 Ha, nice. Ok, so a three-stage release - Etherpad, then platform, then open source platform.

33

34 Probably:

35 1. etherpad (next wed)

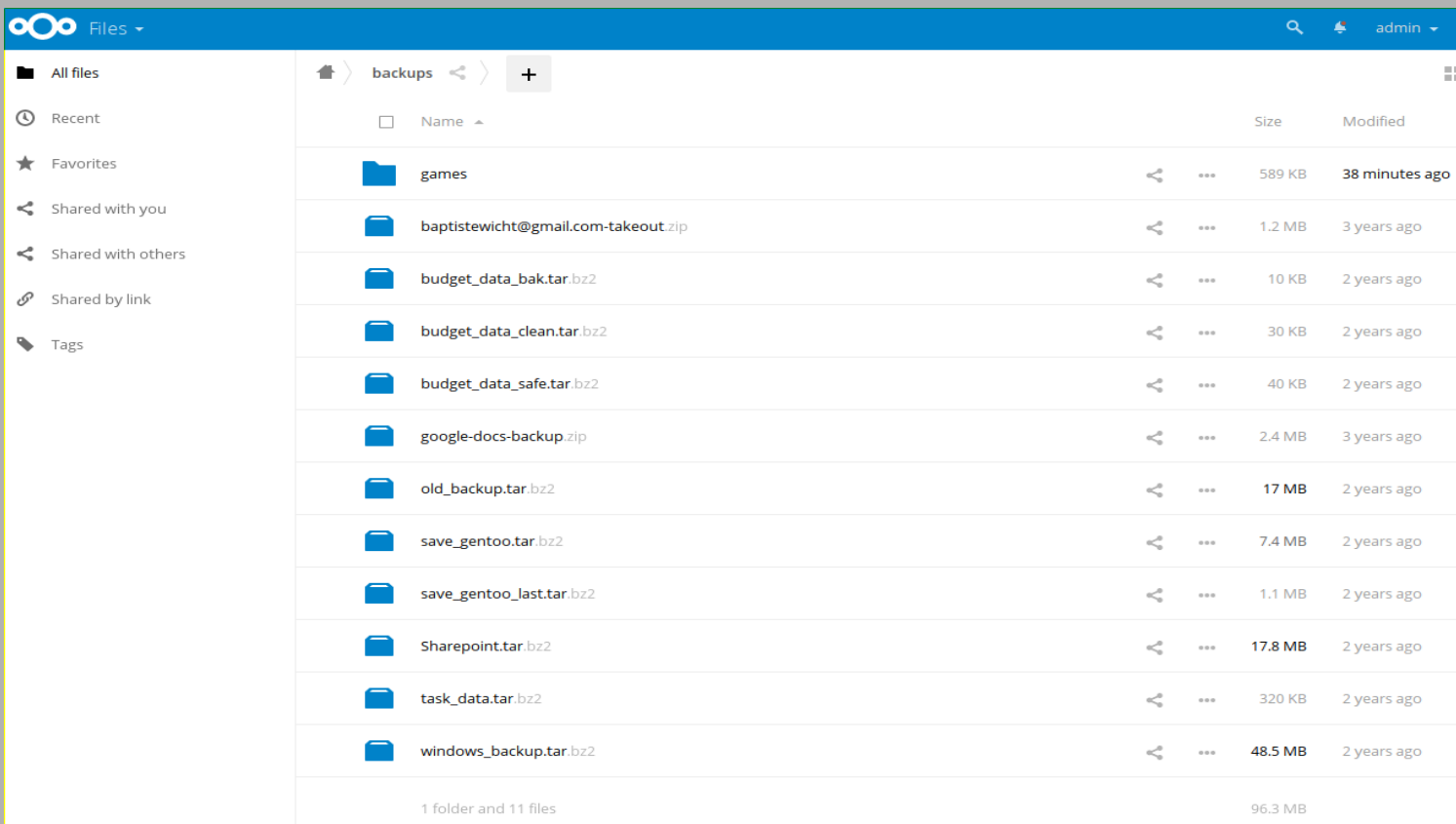
36 2. platform + open source to host yourself (a .jar basically)

37 3. ability to host any app on our servers, utility model

38

Powered by [AppJet](#) →

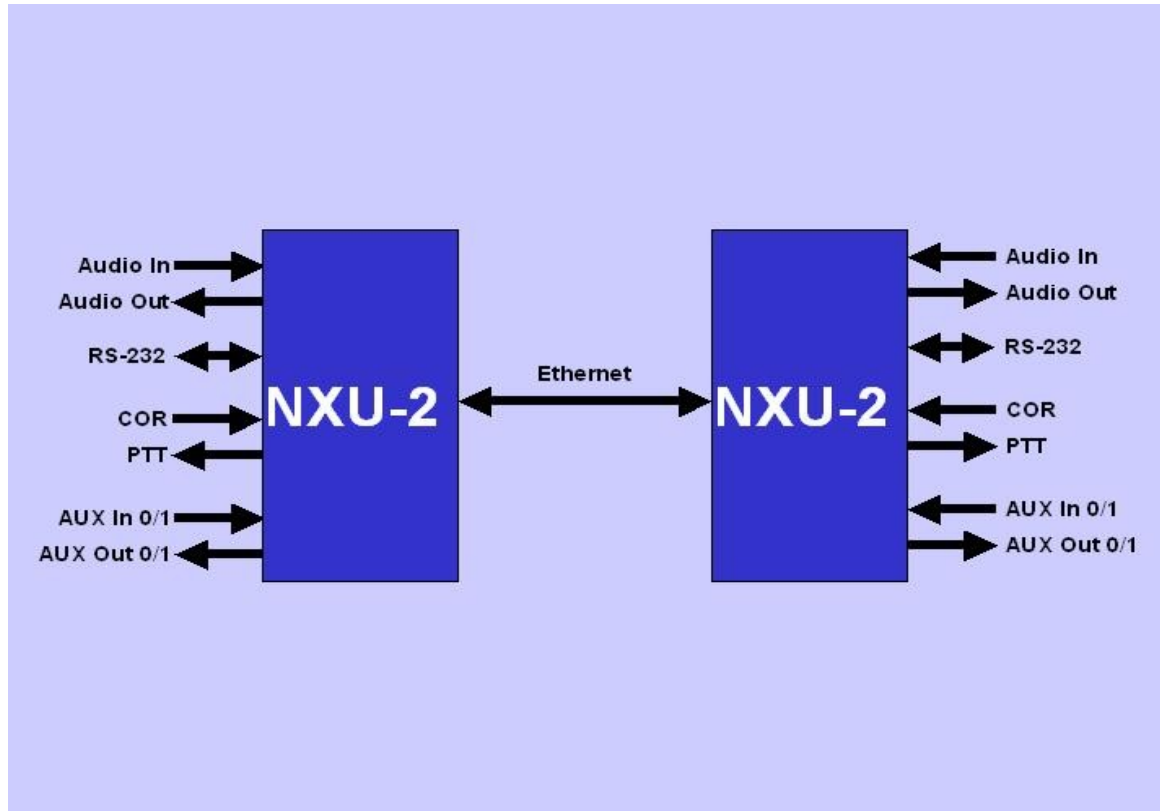
# NextCloud – a drop box



The screenshot displays the NextCloud web interface. The top navigation bar is blue with the NextCloud logo, a 'Files' dropdown menu, a search icon, a notification bell, and a user profile labeled 'admin'. The left sidebar contains a list of navigation options: 'All files', 'Recent', 'Favorites', 'Shared with you', 'Shared with others', 'Shared by link', and 'Tags'. The main content area shows the 'backups' directory. It features a table with columns for 'Name', 'Size', and 'Modified'. The table lists 11 files, each with a folder icon, a share icon, and a three-dot menu icon. The files are: 'games' (589 KB, 38 minutes ago), 'baptistewicht@gmail.com-takeout.zip' (1.2 MB, 3 years ago), 'budget\_data\_bak.tar.bz2' (10 KB, 2 years ago), 'budget\_data\_clean.tar.bz2' (30 KB, 2 years ago), 'budget\_data\_safe.tar.bz2' (40 KB, 2 years ago), 'google-docs-backup.zip' (2.4 MB, 3 years ago), 'old\_backup.tar.bz2' (17 MB, 2 years ago), 'save\_gentoo.tar.bz2' (7.4 MB, 2 years ago), 'save\_gentoo\_last.tar.bz2' (1.1 MB, 2 years ago), 'Sharepoint.tar.bz2' (17.8 MB, 2 years ago), and 'task\_data.tar.bz2' (320 KB, 2 years ago). A summary row at the bottom indicates '1 folder and 11 files' with a total size of '96.3 MB'.

Name	Size	Modified
games	589 KB	38 minutes ago
baptistewicht@gmail.com-takeout.zip	1.2 MB	3 years ago
budget_data_bak.tar.bz2	10 KB	2 years ago
budget_data_clean.tar.bz2	30 KB	2 years ago
budget_data_safe.tar.bz2	40 KB	2 years ago
google-docs-backup.zip	2.4 MB	3 years ago
old_backup.tar.bz2	17 MB	2 years ago
save_gentoo.tar.bz2	7.4 MB	2 years ago
save_gentoo_last.tar.bz2	1.1 MB	2 years ago
Sharepoint.tar.bz2	17.8 MB	2 years ago
task_data.tar.bz2	320 KB	2 years ago
windows_backup.tar.bz2	48.5 MB	2 years ago
1 folder and 11 files	96.3 MB	

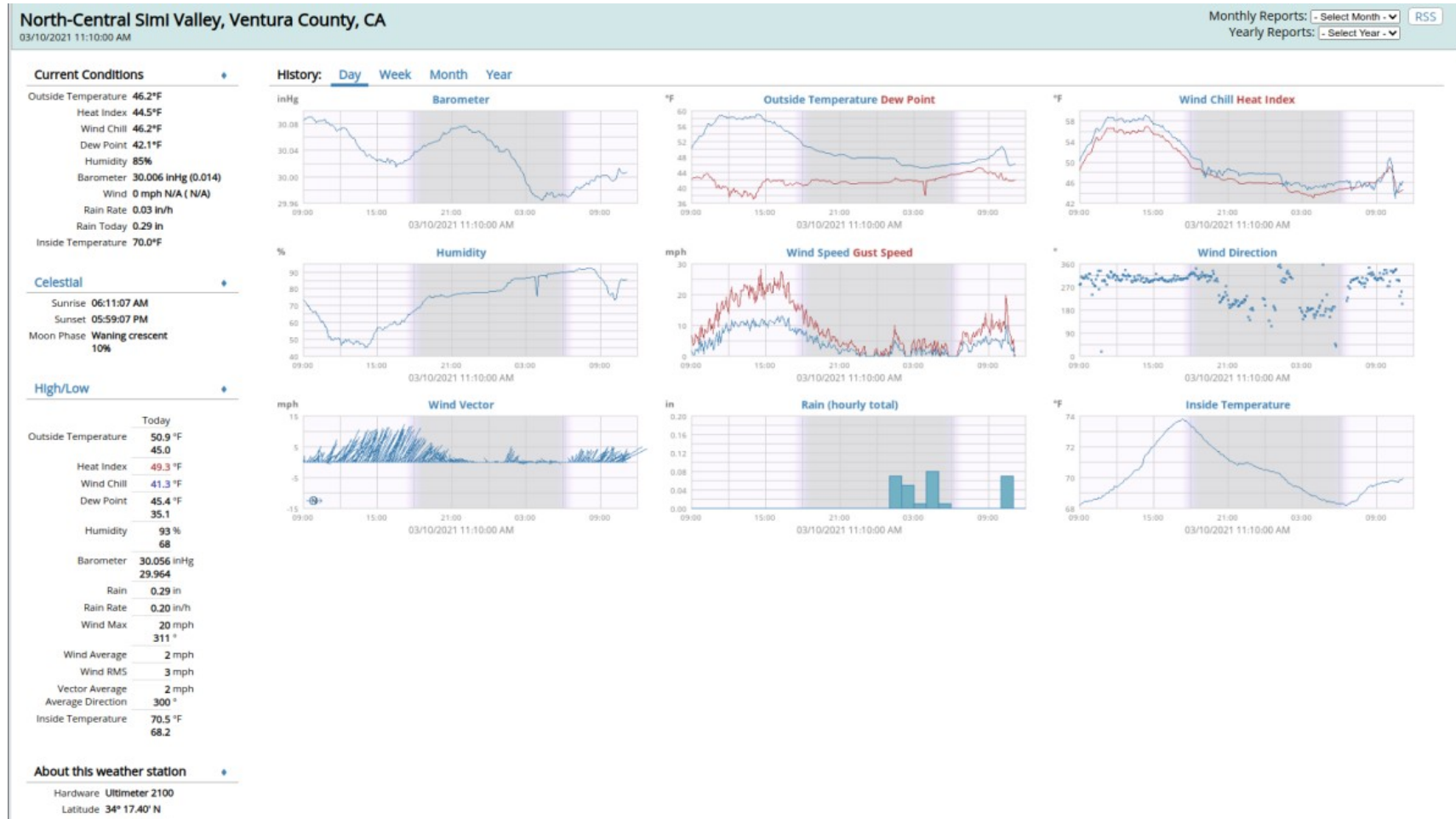
RoIP (Repeater Over IP) repeater linking via equipment from  
JPS Communications, SkyMira, etc.  
Allstar, Dstar & DMR repeaters can be linked via the hamnet, too



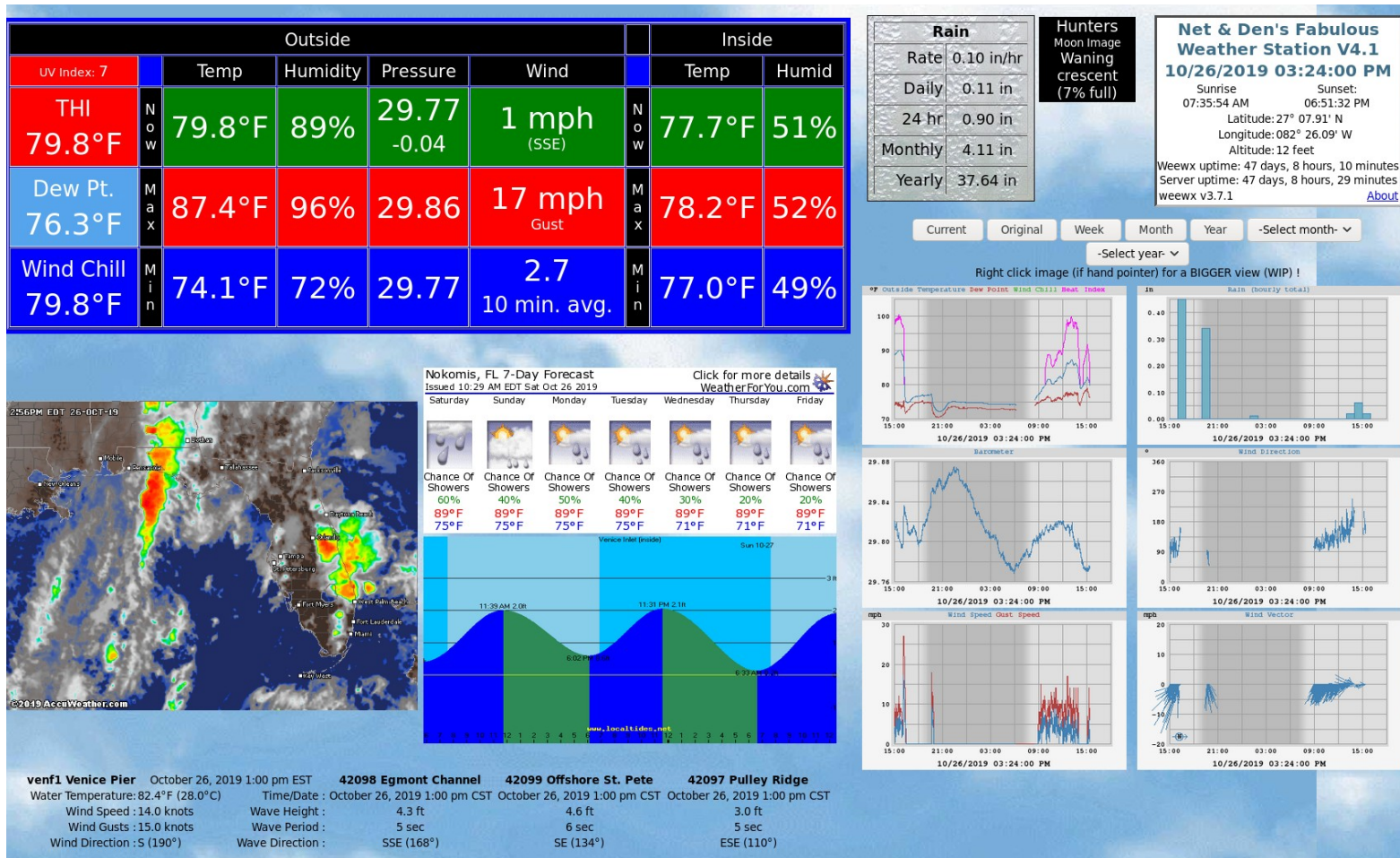


# Put your Weather Station on the hamnet!

## Example uses Weewx software (weewx.com) on an RPI



# Weewx gone wild - highly-customized



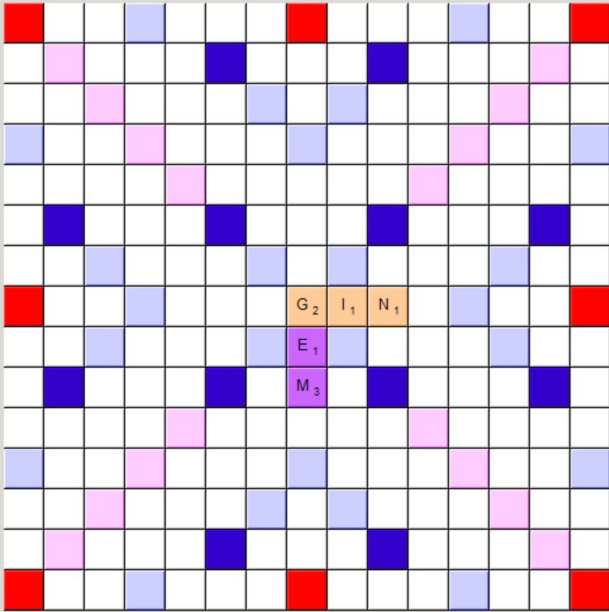
# Gotta have some fun!

## Scrabble server, running on hamnet!

PyScrabble - guest01

File Tools Server View Help

Chat testGame x



**Current Game:**

Player	Score
guest01	0
kg6wxc	8

Save Game Leave Game

Chat Info Spectators Options Letter Distribution

[09:53:20 PM] <GAME> testGame started  
[09:53:20 PM] <GAME> kg6wxc now has control of the board  
[09:53:51 PM] <GAME> kg6wxc has added GIN (8)  
[09:53:51 PM] <GAME> guest01 now has control of the board

S<sub>1</sub> A<sub>1</sub> E<sub>1</sub> E<sub>1</sub> I<sub>1</sub>

Send Move Pass Move Trade Letters Clear Shuffle



# bzflag ("tank") game!

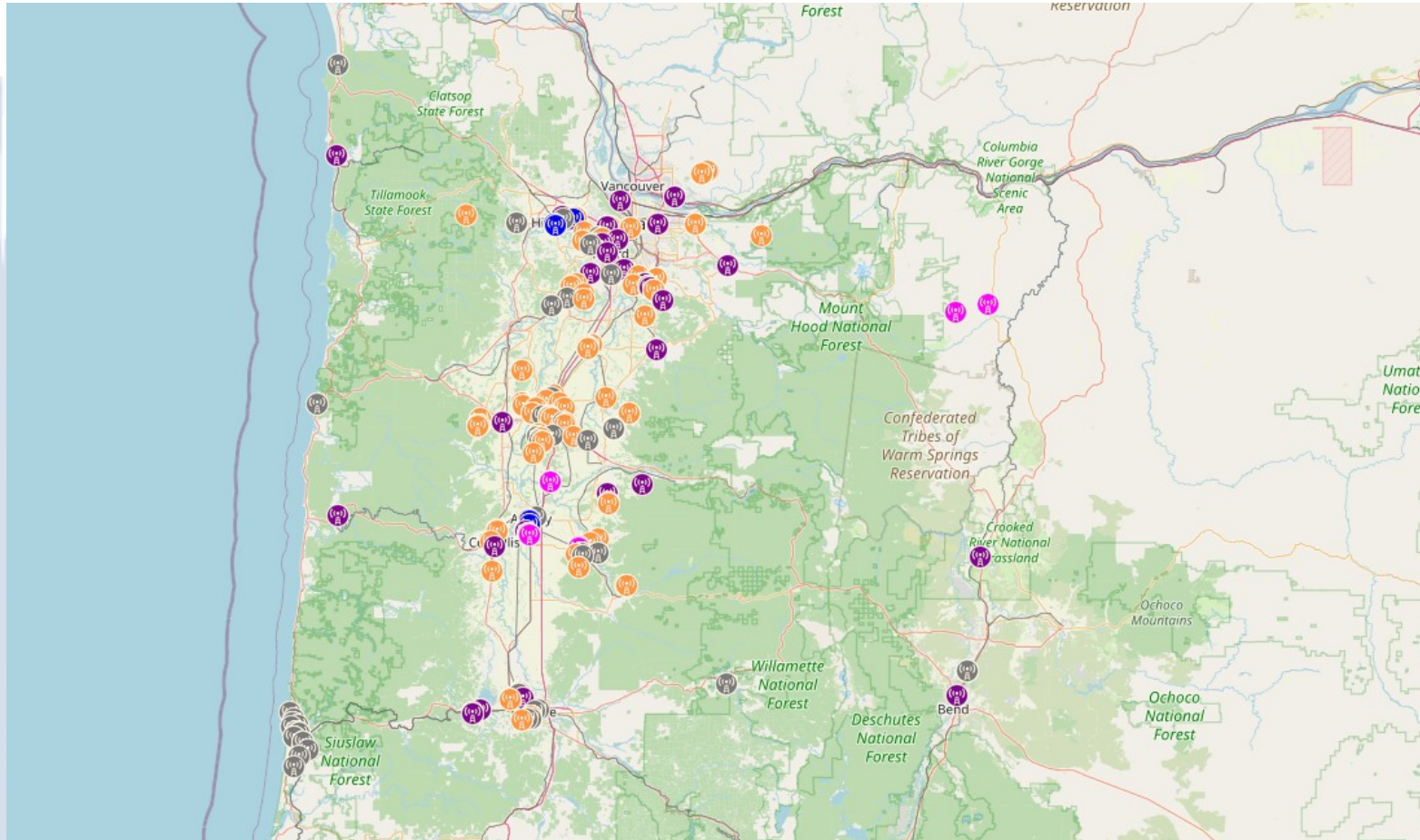


# Texas Hold 'Em server :-)



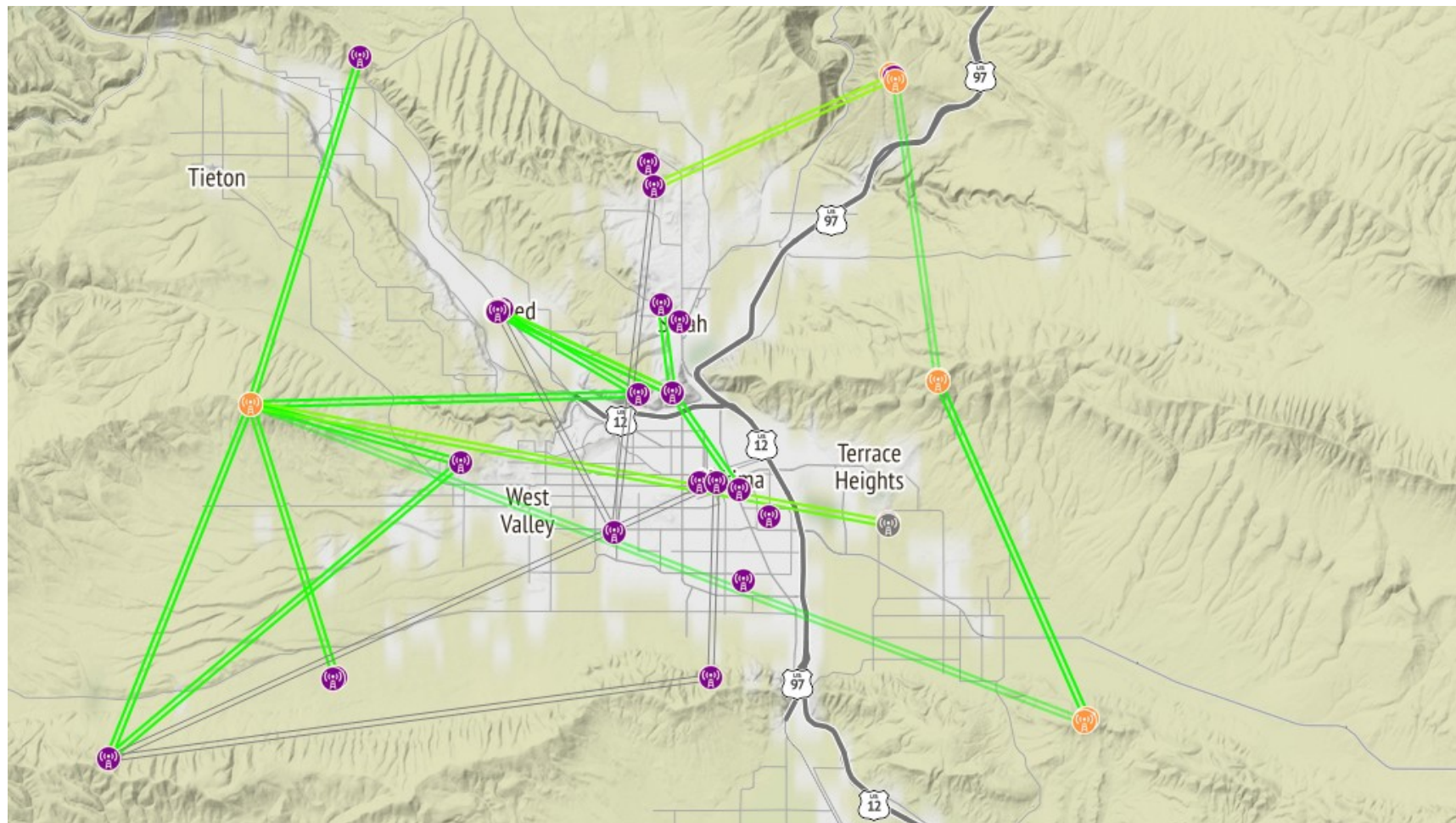


# Network maps from KG6WXC mapping software – Washington/Oregon



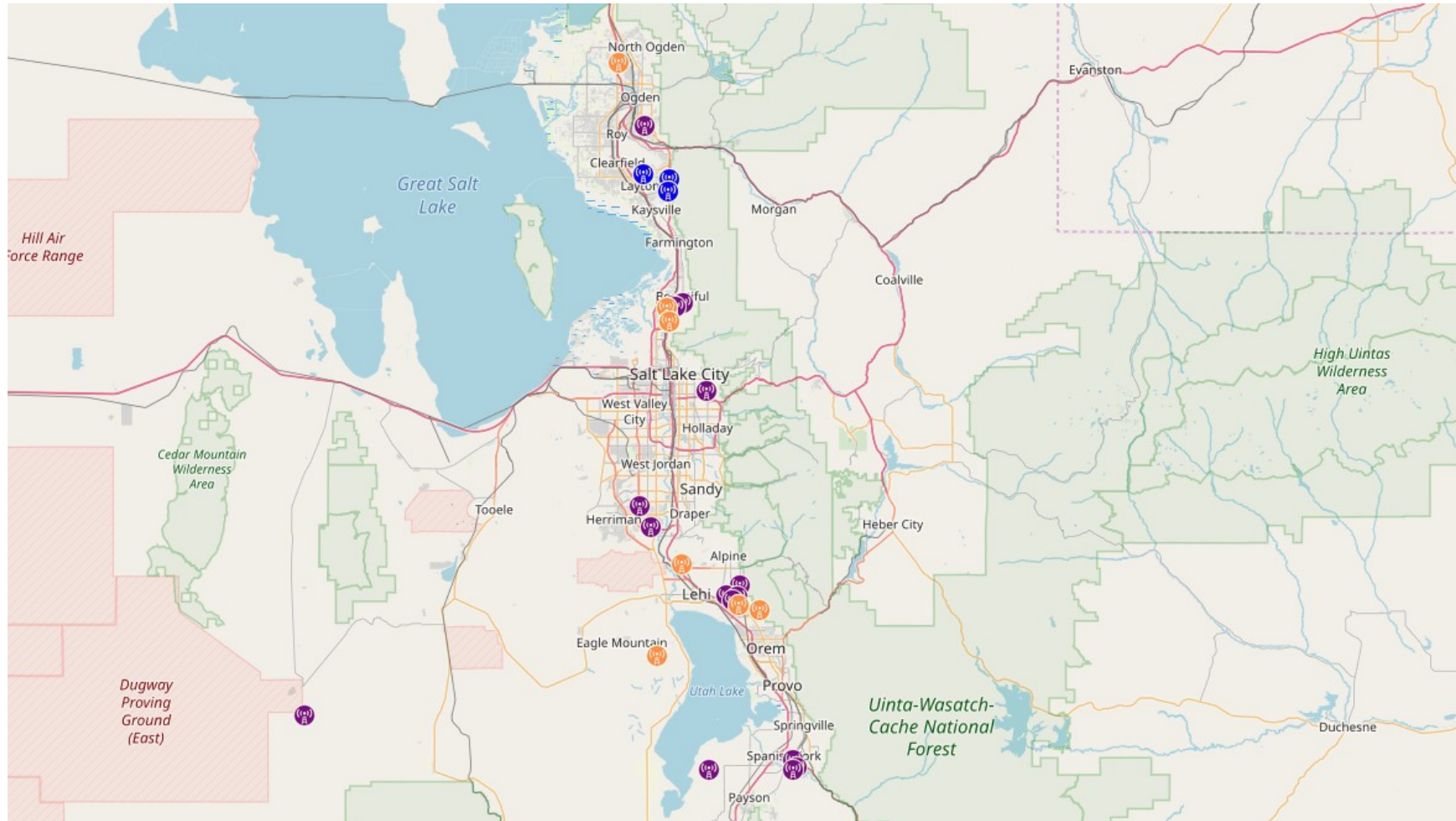
Orange – 5 GHz  
Purple – 2 GHz  
Blue – 3 GHz  
Pink 900 MHz  
Grey – no RF

## Network map – Yakima, WA



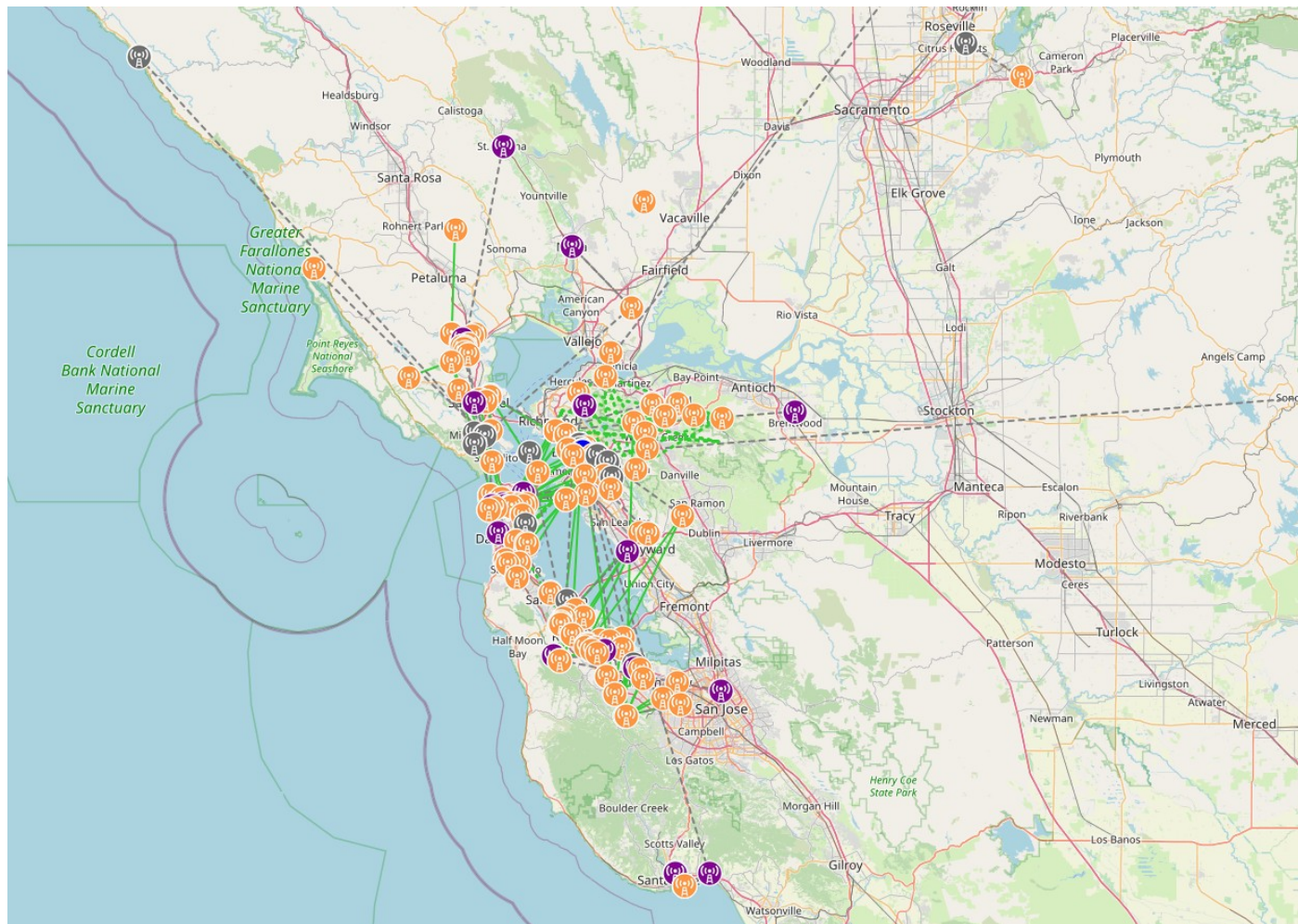


# Network map – Salt Lake City, Utah

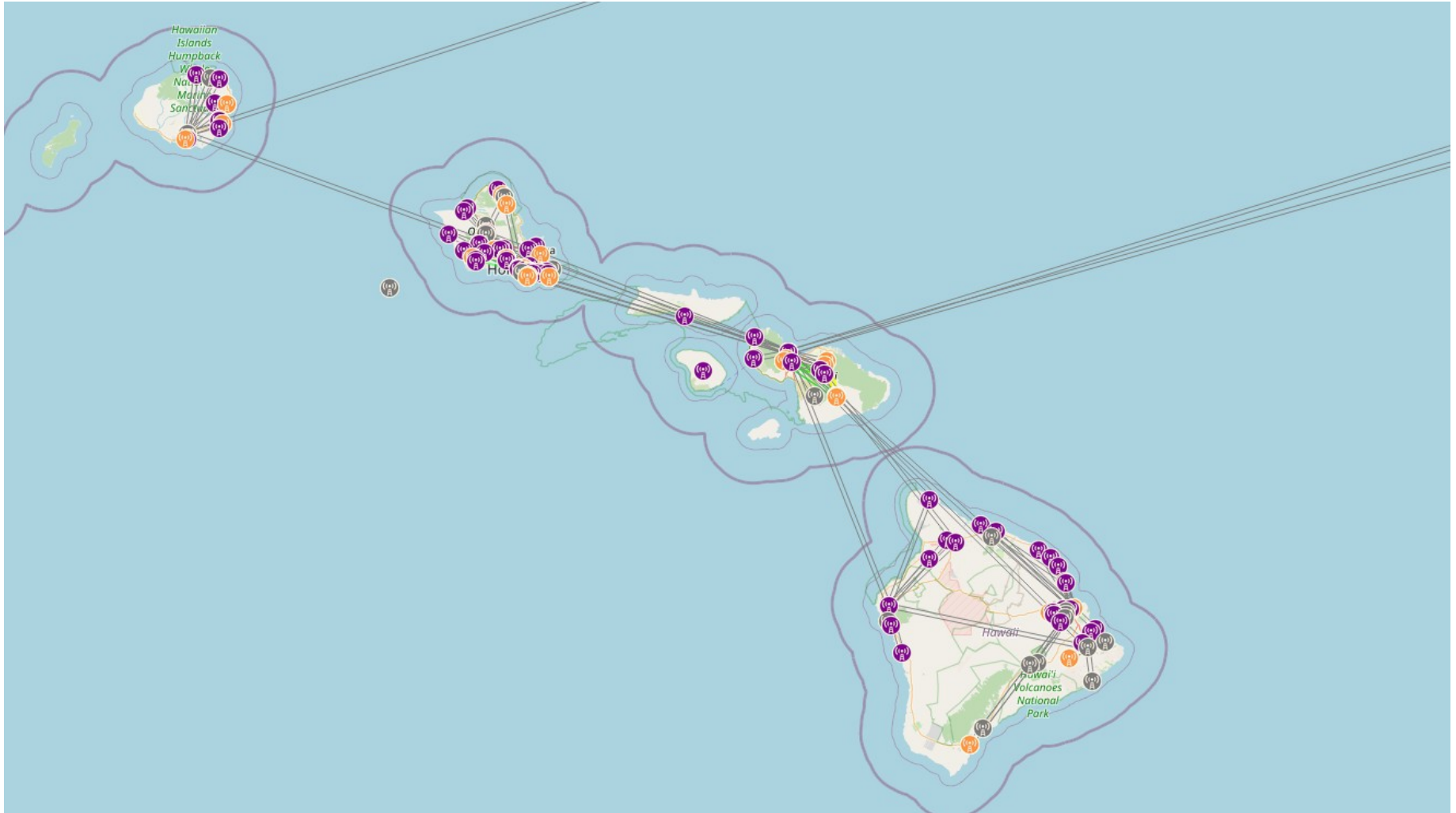




## Network map – BAM (Bay Area Mesh) - San Francisco, CA

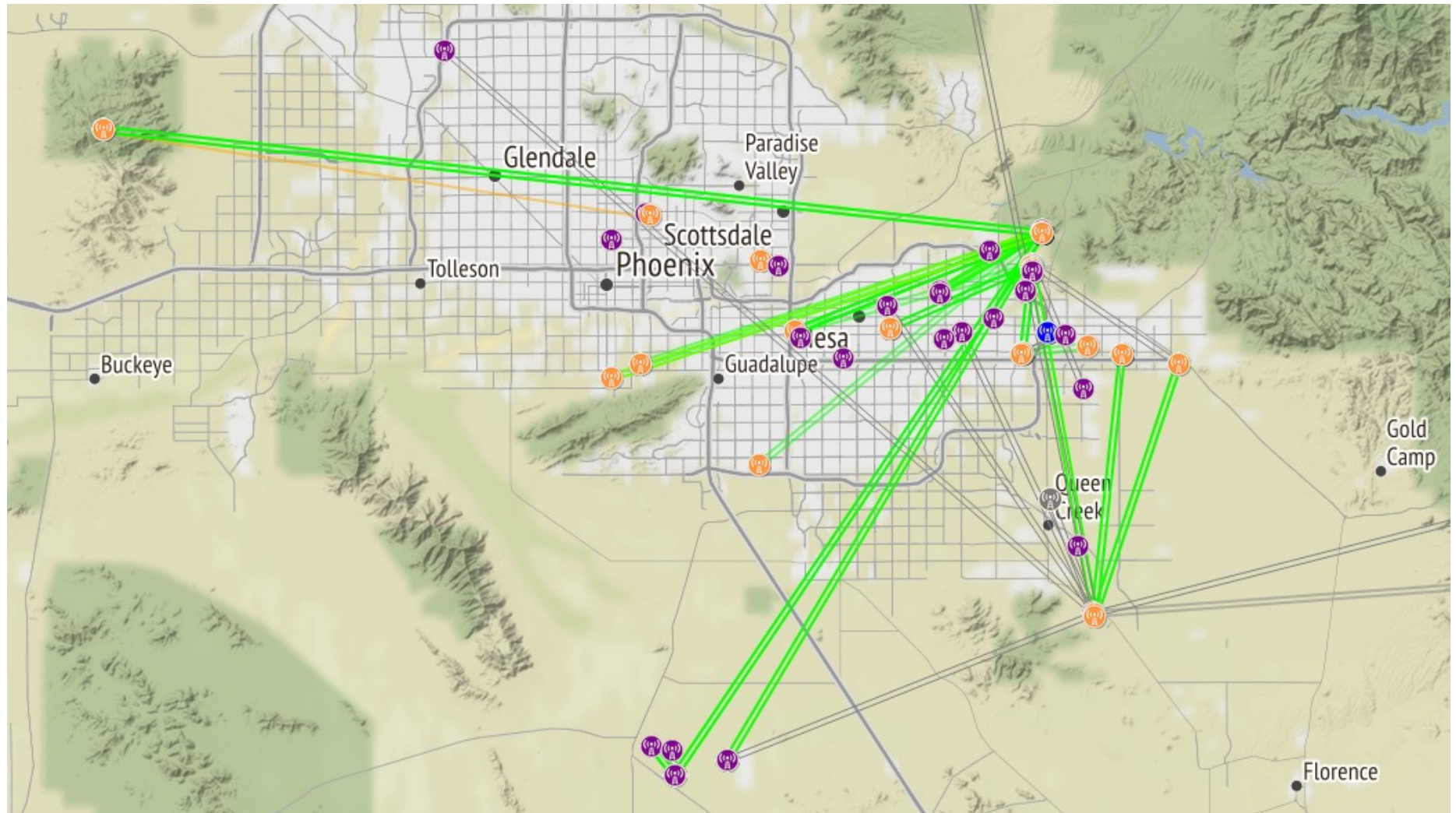


## Network map – Hawaiian Islands





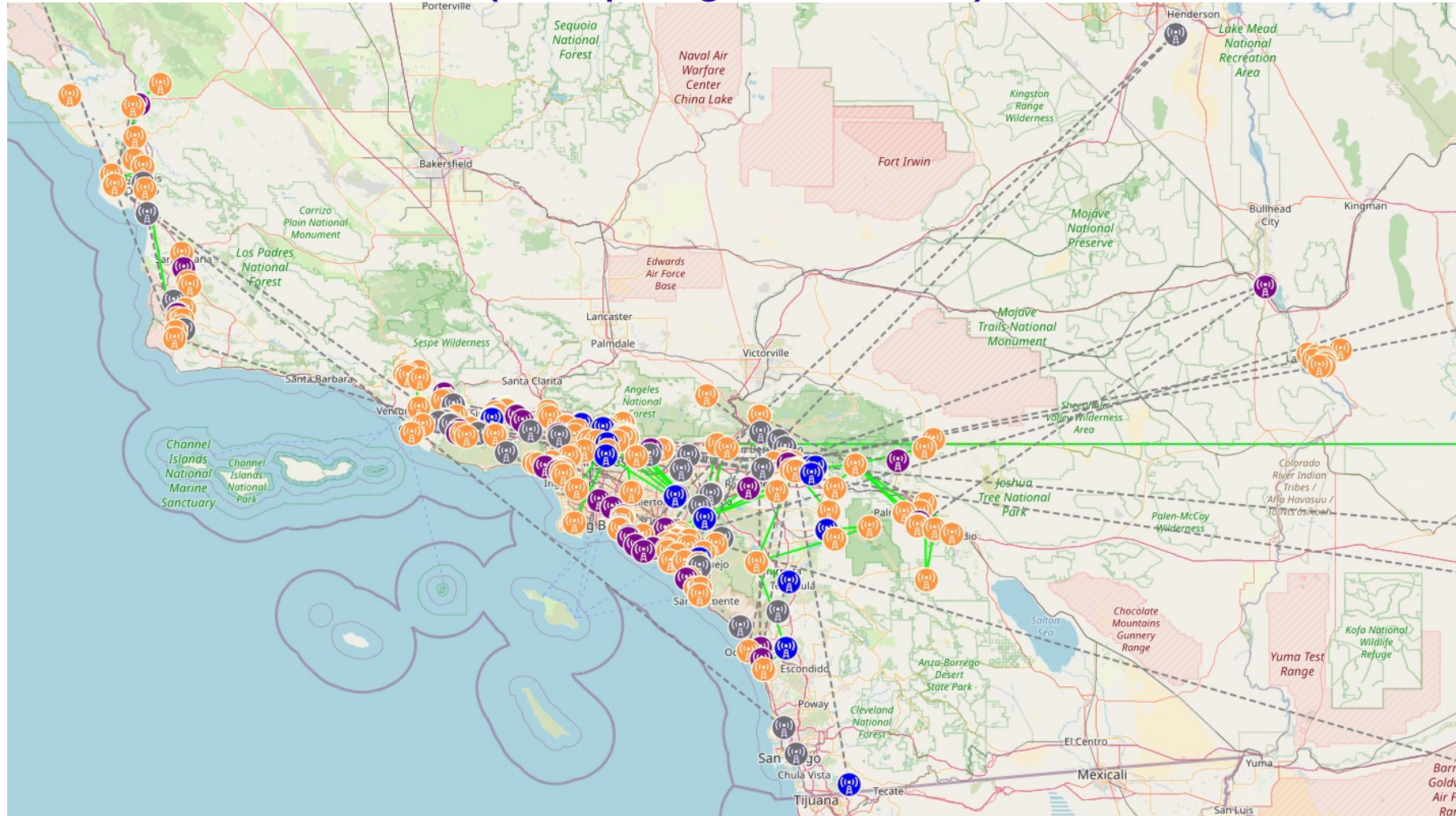
# Network map – Phoenix area





# Network map – Southern California

About 425 nodes (hilltop & ground level) in area shown



# Equipment

What's out there??

## About Modern Access Points/AREDN Nodes

- Available for use in four amateur bands
  - Not expensive
  - (Mostly) designed for outdoor use: weatherproof
  - Sophisticated software-defined transceivers (two for MIMO! - Multiple Input Multiple Output).
  - Built-in gain antennas in many models, one vertically-polarized, one horizontally polarized for two simultaneous data streams – on the same channel!
- Typically 600 mW Tx power (split between two channels)
- MIMO + 802.11n – much better performance than older gear
- POE (Power Over Ethernet): only one cable required to node



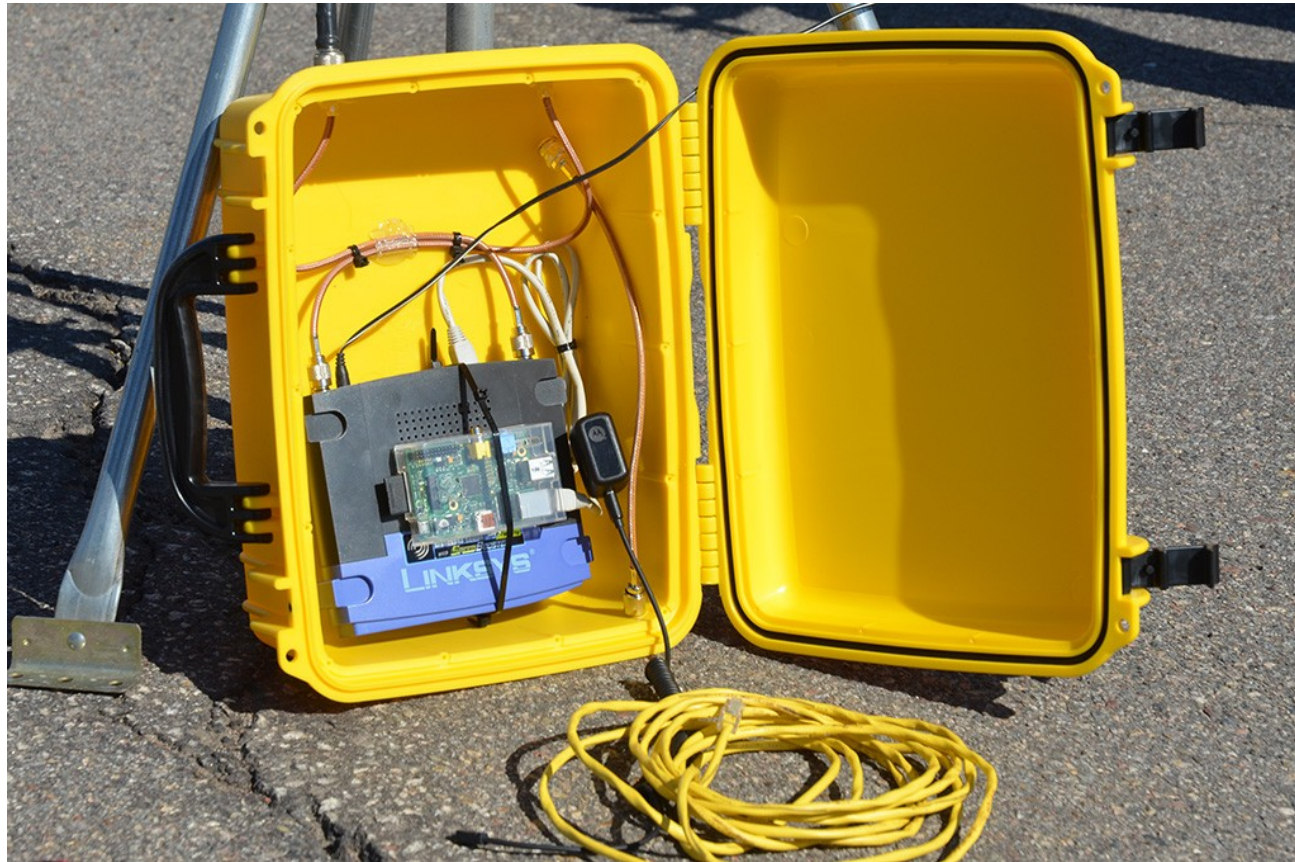
## About Modern Access Points/AREDN Nodes

- *Use caution buying used equipment*
  - ▶ *Don't purchase if they only have 8 MB of flash or 32 MB of RAM; future versions of AREDN firmware may not fit in older 32 MB devices **(many of these older devices have been sunsetted by OpenWrt, and hence AREDN support for them will cease in the future)***
  - ▶ *Don't purchase if they're not MIMO:*
    - *poor performance compared to modern devices*
    - *don't interoperate optimally with MIMO gear (think water & oil);*
  - ▶ *The AREDN website ([arednmesh.org](http://arednmesh.org)) has a Support Platform Matrix that has flagged supported devices that are no longer recommended for new deployments*
- *Now (1Q23) limited support for 802.11ac devices. Check AREDN Nightly Build page for latest info.*

## Old School (ca 2012)

One wireless transceiver, only 60 mW Tx power

Not MIMO, not 802.11n, only 4 MB of Flash, 16 MB of RAM, not weatherproofed



**The next brand of access points  
supported by AREDN was Ubiquiti  
The Ubiquiti Bullet  
600 mW output**



# Ubiquiti Bullet – not MIMO, only 32 MB of RAM



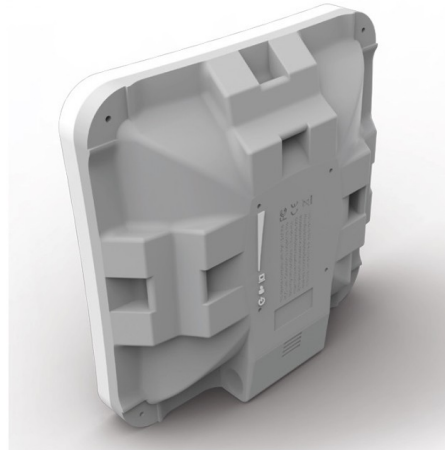
## The next generation for the home QTH was the Ubiquiti Nanostation M2\* & M5\*



\*No longer recommended (by me) for new purchases

# Mikrotik SXTsq 2, 5

Short Haul - ~10-12 miles. Faster CPU, narrower beamwidth than Nanostations



Make sure you buy this too!





## **Ubiquiti PowerBeam M5 300 (mm dia.), M5 400 & M5 620**

Each has higher gain (but narrower beamwidth) than the previous version. Recommended.

(Starting to get scarce new; many now showing up on eBay after being replaced by WISPs – generally good buys)



## Mikrotik LHG 5, LHG HP LHG 5 XL

Becoming very popular. Lighter weight than equivalent Ubiquiti – better for portable work



# Mikrotik LDF (Light Dish Feed) 5

Inexpensive, 9 dBi gain.

(1Q23 – not yet supported in latest nightly builds)





- Mikrotik LDF 5 (5 GHz) installed at dish feedpoint using universal mount (\$8 from Amazon) ~23 dBi gain
- Ideal for hams under an HOA, as satellite dishes are allowed!
- LDF 2 (2 GHz) now also supported by AREDN software

## **Mikrotik LDF 5**

Installed in portable (foldable!) satellite TV dish –  
from K9CQB



# TP-Link – less popular but work very well

- CPE 210, 220, WBS-210 - 2.4 GHZ
- CPE 510, WBS 510 - 5.8 GHz
  - Like Nanostations
- CPE 610 – dish for 5.8 GHz
  - No longer in production; available via eBay
  - Replacement (CPE710) now supported in nightly build (1Q23)





# GL.iNet Products

## AR750 (both Creta & Slate)

- 2.4 GHz & 5.8 GHz\* MIMO
- Range: several hundred yards (no external antennas)
- Useful for Field Day logging or remote access on a network site.
- USB-powered
- Will run for a long time when plugged into a USB battery pack (for use as a relay site).



\*WiFi only; mesh not supported

## Other Network Station Requirements

- Shielded (per Ubiquiti) outdoor network cable. Could be unshielded if lightning isn't an issue in your area (IMO)
  - Pre-terminated lengths are available if you're uncomfortable terminating RJ45 cables
- Needs a dedicated computer for mesh network, because it's a standalone network with no connection to home network (but there's a way around that – see Mikrotik hAP AC Lite slides)
- Clear line of sight, because...

## Line of Sight

"Microwaves can  
go ~~15~~ miles or  
through one tree"

~~25~~  
35



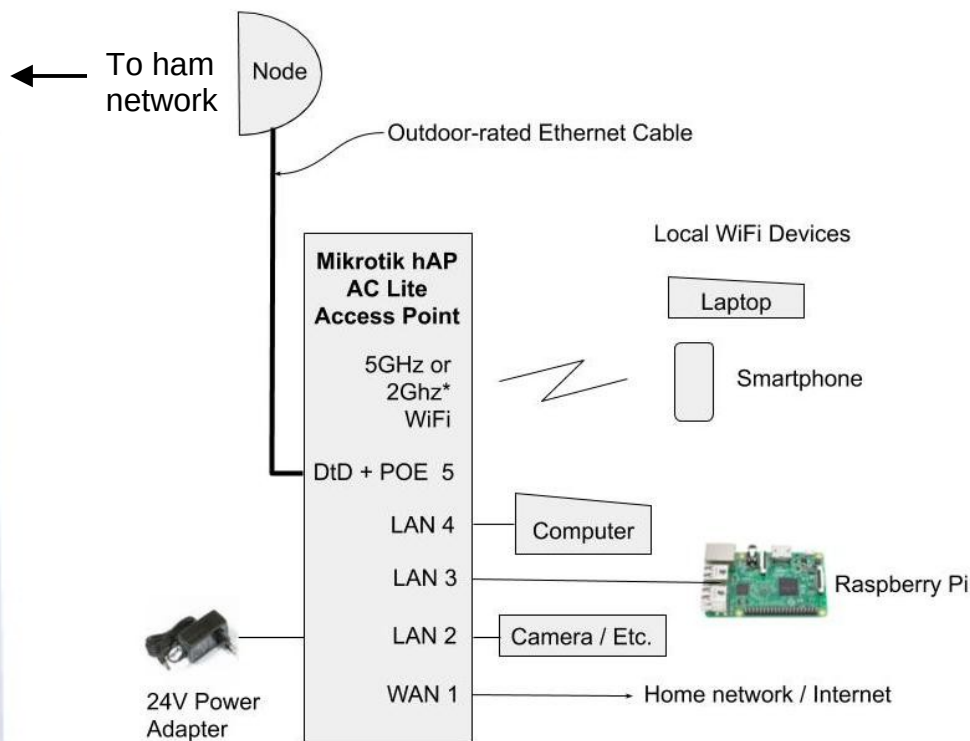
But two's company,  
tree's a crowd...

# Mikrotik hAP AC Lite

The Swiss Army Knife of ham networking  
A valuable addition to a ham shack network



# A Mikrotik hAP Ac Lite running AREDN software integrated into your home network – recommended!



\* 2 GHz may be WiFi or Mesh

- Port 1 – Wired connection to home network
- Ports 2-4 – other devices on your ham network
- Port 5 provides POE power plus DtD (Device to Device) link for routing info to/from node – your link to the mesh network
- 2 & 5 GHz internal radios can be used as ham network node (2 GHz only), a wireless access point or a wireless access client.
- Wired this way, devices on ports 2-4 or connected via the internal wireless access point have access to both the hamnet and the internet.
- The AREDN software firewalls the hamnet off from your home network.

# hAP ac2 & ac3 now supported in nightly builds

Faster CPU w/4 cores, Gigabit Ethernet ports





# Home Installation example

2 GHz & 5 GHz Nanostations, (for redundancy)  
Station is three miles from hilltop site



# Home Installation example

Ubiquiti Nanostation & Mikrotik dish

Ethernet cable goes to Nanostation main port. Secondary port goes to Mikrotik dish, providing POE and network connectivity. Only one Ethernet cable up the mast is required!



# Home Installation example

Ubiquiti Powerbeam for network backbone link;  
Ubiquiti Rocket + sector antenna for local redistribution





# Hilltop equipment – Ubiquiti 120 degree sector antenna with Rocket M5 5.8 GHz node attached on back



# Small site Example - North Orange County, California

120 degree sector antennas & nodes for 2.4, 3 & 5 GHz





## Medium Site Example – Chatsworth Peak, California

User access points on 2.4 & 5 GHz; dish for backbone link; PTZ camera

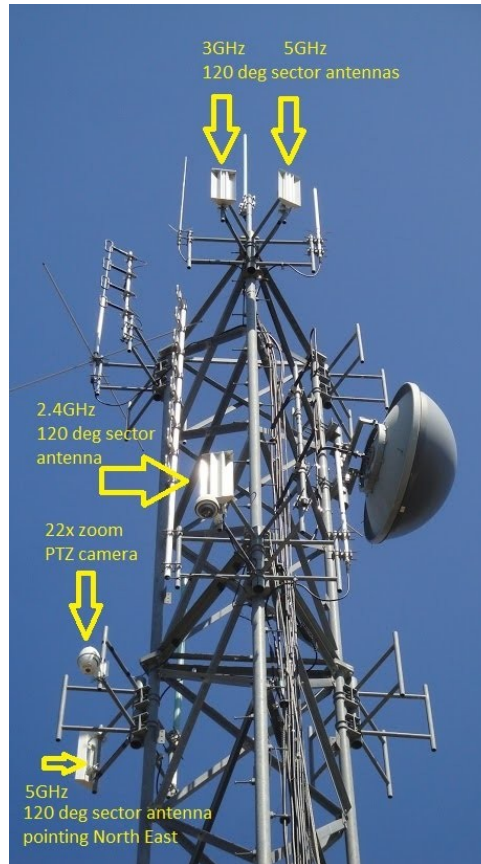


**Another medium-sized site (post wind-storm)**  
(80% FM repeaters, 20% networking) Verdugo Peak, California



# Large site (commercial) Pleasants Peak, California

Yellow-highlighted gear is for mesh network. 360 degree user access, backbone links (not shown) + PTZ camera



# Ham Radio Allocations – 2.4 & 3 GHz

AREDN Offers 2 Non-Shared Channels on 2.4 GHz

2.4 GHz	Channel	-2	-1	0*	1	2	3	4	5	6
	Status	Ham Band			Shared Ham and ISM/WiFi Band					
	Freq	2.397	2.402	2.407	2.412	2.417	2.422	2.427	2.432	2.437

\*Not available for use

Only one usable 10 MHz channel. Splatter from Part 15 limits usefulness

Channel	76	77	78	79	80	81	82	83	84	85	86	87
Status	Ham Band (continues indefinitely, pending future FCC action)											
Freq	3.380	3.385	3.390	3.395	3.400	3.405	3.410	3.415	3.420	3.425	3.430	3.435
	88	89	90	91	92	93	94	95	96	97	98	99
	Eliminated early 2022											
	3.440	3.445	3.450	3.455	3.460	3.465	3.470	3.475	3.480	3.485	3.490	3.495



# Ham Radio Allocations – 5 GHz

52 Channels, 14 Non-Shared, on 5.8 GHz

5.8 GHz	Channel	133	134	135	136	137	138	139	140	141	142	143	144	145
	Status	Ham Band shared with U-NII-2C/wifi/unlicensed												
	Freq	5.665	5.670	5.675	5.680	5.685	5.690	5.695	5.700	5.705	5.710	5.715	5.720	5.725
	Channel	146	147	148	149	150	151	152	153	154	155	156	157	158
	Status	Ham Band shared with U-NII-3/wifi/unlicensed												
	Freq	5.730	5.735	5.740	5.745	5.750	5.755	5.760	5.765	5.770	5.775	5.780	5.785	5.790
	Channel	159	160	161	162	163	164	165	166	167	168	169	170	171
	Status	Ham Band shared with U-NII-3/wifi/unlicensed												
	Freq	5.795	5.800	5.805	5.810	5.815	5.820	5.825	5.830	5.835	5.840	5.845	5.850	5.855
	Channel	172	173	174	175	176	177	178	179	180	181	182	183	184
	Status	Ham Band												
	Freq	5.860	5.865	5.870	5.875	5.880	5.885	5.890	5.895	5.900	5.905	5.910	5.915	5.920

Refer to your local band plan for coordination; ★ 5825 to 5850 Shared under Part 15.247 with a limited number of WISP operators and may be encountered at tower sites

11/2020 – FCC removed DOT's primary allocation (they hadn't started using it). We kept our secondary allocation but the FCC is now letting Part 15 users expand into channels 167-184. Over time, expect channel noise levels to rise in those channels. Plan on deploying higher gain devices than you currently need to future-proof installations (e.g., dishes instead of Nanostations).

**Note** – WISPS are limited to 1000mW EIRP in channels 133-145, whereas ham are not – consider these channels for hilltop backbone links.



# The AREDN node interface (main screen)

## K6PVR-VC-SimiEast-5G

**Location:** 34.260 -118.642

90 degree sector and Rocket M5 servicing east Simi Valley. Antenna bearing approximately 300 degrees

[Help](#)

Refresh

Mesh Status

Neighbor Status

WiFi Scan

Setup

Select a theme ▼

<b>Wifi address</b>	10.198.175.154 / 8	<b>Signal/Noise/Ratio</b>	-64 / -95 / 31 dB	<a href="#">Charts</a>
<b>LAN address</b>	10.53.124.209 / 29	<b>firmware version</b>	1901-737bd10	
<b>WAN address</b>	none	<b>model</b>	Ubiquiti Rocket M5 XW	
<b>default gateway</b>	10.200.237.222 W6BI-VC-QTH-5G	<b>system time</b>	Mon Nov 14 2022 11:07:53 PST	
<b>SSID</b>	AREDN-10-v3	<b>uptime</b>	0:04	
<b>Channel</b>	170	<b>load average</b>	0.36, 0.33, 0.15	
<b>Bandwidth</b>	10 MHz	<b>available space</b>	flash = 2448 KB memory = 35700 KB	
		<b>Host Entries</b>	Total = 1536 Nodes = 557	

# The AREDN node interface – mesh status page

## K6PVR-VC-SimiEast-5G mesh status

Location: 34.260 -118.642  
90 degree sector and Rocket M5 servicing east Simi Valley. Antenna bearing approximately 300 degrees

[Help](#)

Node Name	Lan Hostname	Service Name
K6PVR-VC-SimiEast-5G	simieast-srv simieast-phone simieast-cam1 k6pvr-tt-svr	<a href="#">Site-Info</a> <a href="#">Simi-east-ptz-cam</a> <a href="#">Teamtalk</a>

Current Neighbor	Lan Hostname	LQ	NLQ	TxBps	Service Name
<a href="#">K6PVR-VC-SimiEast-2G</a> (dtd)		100%	100%		
<a href="#">K6PVR-VC-SimiEast-3G</a> (dtd)		100%	100%		
<a href="#">KJ6GEU-VC-QTH-5G</a>		29%	98%		VoIP Phone 10*180*19*163
<a href="#">W6BI-VC-QTH-5G</a>		82%	91%	65.0	
<a href="#">W6BI-VC-SVPD-5G</a>	Pt-15-WAP	57%	99%	54.9	
<a href="#">WA6GNB-VC-QTH-5G</a>		72%	100%		
<a href="#">WB2YXY-VC-5G</a>	wb2yxy-mesh-server	48%	98%	26.0	NTP (GPS w/ 1PPS stratum 1) IPERF & IPERF3 <a href="#">Node info</a> <a href="#">Weather station</a> <a href="#">IRC</a> <a href="#">FTP</a> <a href="#">Webcam snapshots</a> Asterisk PBX (10.38.100.194)
	wb2yxy-mesh-pbx				

Remote Nodes	LAN Hostname	ETX	Service Name
<a href="#">K6PVR-VC-West-SouthMtn-SE-5G</a> (tun*2)		0.20	
<a href="#">N6FL-VC-Reeves-Rd-to-Black-Mtn-Link-5G</a>		0.30	
<a href="#">N6FL-VC-Ojai-East-5G</a>		0.30	
<a href="#">K6PVR-VC-West-SouthMtn-W-5G</a>		0.30	
<a href="#">N6FL-VC-OjaiEast-W-Sector-2G</a>		0.30	
<a href="#">K6PVR-VC-Camarillo-Hills-SW-5G</a> (tun*4)		0.30	
<a href="#">K6PVR-VC-Sulphur-to-Oxnard-5G</a>		0.30	
<a href="#">K6PVR-VC-RasnowPk-N-Sector-5G</a> (tun*1)		0.40	
<a href="#">K6PVR-VC-ResourceServer</a> (tun*1)		0.40	
	k6pvr-linux		k6pvr-linux-srv

This node

Local neighbors and the services they are providing

Remote nodes (more than one hop)

# The mesh status page

K6PVR-VC-SimiEast-5G mesh status				
Location: 34.260 -118.642 90 degree sector and Rocket M5 servicing east Simi Valley. Antenna bearing approximately 300 degrees				
<a href="#">Help</a> <a href="#">Refresh</a> <a href="#">Auto</a> <a href="#">Quit</a>				
Node Name	Lan Hostname	Service Name		
K6PVR-VC-SimiEast-5G	simieast-srv simieast-phone simieast-cam1 k6pvr-rt-svr	<a href="#">Site-Info</a> <a href="#">Simi-east-rtz-cam</a> <a href="#">Teamtalk</a>		
Current Neighbor	Lan Hostname	LQ	NLQ	TxMbps
K6PVR-VC-SimiEast-2G (dtd)		100%	100%	
K6PVR-VC-SimiEast-3G (dtd)		100%	100%	
KJ6GEU-VC-QTH-5G		29%	98%	
W6BI-VC-QTH-5G		82%	91%	65.0
W6BI-VC-SVPD-5G	Pt-15-WAP	57%	99%	54.9
WA6GNB-VC-QTH-5G		72%	100%	
WB2YXY-VC-5G	wb2yxy-mesh-server	48%	98%	26.0
	wb2yxy-mesh-pbx			
Remote Nodes	LAN Hostname	ETX		
K6PVR-VC-West-SouthMtn-SE-5G (tun*2)		0.20		
N6FL-VC-Reeves-Rd-to-Black-Mtn-Link-5G		0.30		
N6FL-VC-Ojai-East-5G		0.30		
K6PVR-VC-West-SouthMtn-W-5G		0.30		
N6FL-VC-OjaiEast-W-Sector-2G		0.30		
K6PVR-VC-Camarillo-Hillis-SW-5G (tun*4)		0.30		
K6PVR-VC-Sulphur-to-Oxnard-5G		0.30		
K6PVR-VC-RasnowPk-N-Sector-5G (tun*1)		0.40		
K6PVR-VC-ResourceServer (tun*1)		0.40		
	k6pvr-linux			
	k6pvr-linux-srv			

Local linked neighbors  
(not direct RF;  
DtD via Ethernet cable,  
or other)

LQ – Link Quality  
NLQ – Neighbor Link  
Quality

TxMbps - Modulation  
rate times actual packet  
success rate

Local RF  
neighbors

Services provided by  
this node

$ETX = 1 / (NLQ * LQ)$  per hop.  
End to end ETX is sum of the  
ETXes of all the hops.

# Where to get AREDN Ham Network Info

- Amateur Radio Emergency Data Network ([arednmesh.org](http://arednmesh.org))
  - List of supported products
  - Software downloads (production & nightly builds)
  - How-Tos
  - FAQs
  - Extensive, detailed documentation
  - Forums – more than 4,100 users
- Social media sites: Facebook, Mastodon, Slack, Discord, etc.
- AREDN channel on YouTube
  - \* Beware of older HSMM and AREDN YouTube videos; they can be way out of date.

## Coverage Tools (can two sites 'see' each other?)

- [heywhatsthat.com](http://heywhatsthat.com) – easy to use
- <https://www.scadacore.com/tools/rf-path/rf-line-of-sight/> - easy
- <https://ispdesign.ui.com/#> - easy to moderate
- Radio Mobile - complex
  - <http://www.ve2dbe.com/english1.html>
- [Radiofresnel.com](http://Radiofresnel.com) – for calculating Fresnel zones
- Mapping and Distance - <https://www.acscdg.com/>



## How do I Get Started?

- Ask around your club; ask around repeaters and/or mailing lists
- Get a link going (may require some tree trimming)
- Or tunnel someplace, if no RF link
- Make friends with repeater owners! (Especially if site is line of sight to you) Point out the advantages of being networked :-)
- Join the AREDN forums and/or any local mailing lists. Read!

# Important notes!

- Do **not** stand in front of the radio for extended periods of time when it's powered on. NEVER look into the focus of the radio when it's powered on. The small dishes have 80 - 100 watts of ERP at 5.8 GHz!
- The Mikrotik Basebox 2 has 30 dBm of power output. When fed to a Mikrotik 30dBi gain dish that's **1 KW** of ERP. **Use caution!**